Section VIII: M&V Plan Overviews for Other Project Categories

This section includes information on M&V methods for federal performance contracts that involve projects other than conventional water conservation and/or energy-efficiency opportunities.

Chapter	Project Description	Method Number
32	New construction projects	NC-A-01 NC-B-01 NC-C-01 NC-C-02 NC-D-01
33	Operations and maintenance measures	OM-01
34	Cogeneration projects	COG-01
35	Renewable energy projects	REN-01

Methods:
NC-A-01
NC-B-01
NC-C-01
NC-C-02
NC-D-01

32 New Construction Projects

32.1 Introduction

Construction of new buildings represents an opportunity to achieve energy savings through performance contracting. Capital budgets are usually limited for new building projects and consequently many energy conservation measures, which may require more capital for equipment purchase or more integrated (and costly) design, are not included. The result can be a significant and unnecessary increase in a building's operating cost and more importantly, a lost opportunity to obtain cost-effective energy savings over the typical 50-year life of a building.

Performance-based contracts may be used to produce energy-efficient buildings. The ESCO's involvement in a new construction project may range from providing single ECMs to providing multiple, interacting ECMs or providing fully integrated building designs.

32.2 Project Definition

The projects covered by these verification plans include any ECM in new construction that can be reasonably modeled with accepted engineering practices. Such projects may include lighting, motors, controls, and HVAC. The projects may be as simple as replacing lighting fixtures with more efficient fixtures or as complex as the integrated design of ECMs in the building architecture.

Project definition in new construction is critical, as the "baseline" building only exists in concept, not in physical reality. The baseline energy performance is obtained from a model of the baseline building. Depending on the complexity of the project, the building may be modeled by calculations in a simple spreadsheet or by a thorough description of the complete building in a whole-building computer simulation analysis.

In addition, the installed ECMs in the energy-efficient building, as in any retrofit project, must be verified. In new construction, projects verification may be simple inspection and spot checking and/or metering of lighting or motor ECMs, or through well-documented commissioning processes for complex ECMs, such as HVAC or controls systems.

32.3 Overview Of New Construction M&V Options

32.3.1 General

In all new construction M&V options, the energy performance of the baseline must meet current building energy codes and standards. For federal agencies, the Energy Policy Act of 1992 requires that new non-residential buildings must meet or exceed ASHRAE Building Energy Efficiency Standard 90.1. In most situations this standard will be used to define the baseline. Defining 90.1 is not necessarily straightforward or easy. All energy savings estimates are obtained from comparison with this baseline.

This section presents five new construction M&V options, which are similar in concept to the retrofit M&V options:

- Option NC-A-01: Stipulated baseline and savings, verified equipment performance.
- Option NC-B-01: Stipulated baseline, savings based on verified equipment performance and estimating tool using short-or long-term measurements
- Option NC-C-01: Whole-building baseline simulation, savings based on difference with actual billing data, verified ECM performance
- Option NC-C-02: Stipulated baseline, savings based on comparison with similar buildings with and without ECMs
- Option NC-D-01: Calibrated whole-building simulation of as-built building, baseline performance defined by “ECM Subtraction Technique,” verified ECM performance.

32.3.2 Steps Common to All M&V Options

The basic steps in new construction M&V are similar to those in retrofit M&V. These steps are as follows:[1]

1. **Define the Baseline.** Baseline definition is a two-part process. First, a design baseline must be developed. This can be the stipulation of specific baseline equipment or specifying whole-building compliance with energy codes or standards. Once the design baseline has been established, analytical tools are used to estimate the associated energy performance of the baseline.
2. **Define Energy-Efficient Design and Projected Savings.** The energy-efficient design is defined through the building design process and is the natural final outcome of that process. Analytical tools are used to estimate performance of the energy-efficient design. First year estimated savings are determined by subtraction of energy efficient design use from baseline use. The estimation process should also include the identification and quantification of factors which could affect the

1. The steps are similar to those defined in the International Performance Measurement and Verification Protocol (IPMVP), 1997.

performance of both the baseline and energy-efficient design, and how these factors will impact energy performance.

3. **Define General M&V Approach.** This chapter presents new building M&V methods that are roughly analogous to the M&V retrofit Options A, B, C, and D, which are presented earlier in this guideline. Options A and B are directed at end-use measures, and Options C and D address whole-building M&V methods. The relative suitability of each approach is a function of:

   – The M&V objectives and the requirements of any related performance contracts.

   – The number of ECMs and the degree of interaction with each other as well as with other systems.

   – The technical practicality and issues associated with M&V of particular ECMs or broader whole-building ECMs and strategies.

   – Current trends toward more integrated and holistic new building designs, which are moving M&V requirements more to the whole-building methods.

   The definition of the general M&V approach should also include a description of how savings will be determined. This section should include the equations that determine energy and demand savings and the conditions under which the equations are used. The assumptions made in developing the data used in the equations should be described as well. Any supporting calculations that are made to manipulate the data (e.g., statistical sampling of lighting fixture operating hours, determining plug load densities) must be documented.

4. **Prepare Project-Specific M&V Plan.** Development of an M&V plan should begin during the design phase of the project. It should include the definition of the baseline building, the definition of the energy-efficient building, and a description of how the ECMs will be verified, what data will be collected, what analytical tools will be used, how savings will be determined (including equations), and what annual activities will be performed and reported.

   The project-specific M&V plan also describes the scope of the project and all issues pertaining to savings determination. These issues are listed in part 32.5. Starting the M&V plan development early in the process forces the development of commissioning plans and O&M procedures for ECMs where necessary. Commissioning and O&M procedures are in the ESCOs interest to ensure savings are realized over the course of the project.

5. **Verify Installation and Commissioning of ECMs or Energy-Efficient Strategies.** Installation and proper operation is verified through site inspections and spot measurements as necessary, combined with review of commissioning reports, fluid balancing reports, etc. Any deviations should be noted and addressed when determining the performance of the energy-efficient building.

6. **Determine Savings Under Actual Post-Installation Conditions.** Virtually all energy performance projections are predicated upon certain assumptions regarding operational conditions, such as occupancy and weather. This affects both the baseline and energy-efficient design estimations. Deviations from the operational assumptions must be tracked by an appropriate mechanism (i.e., a site survey, short-and/or long-term metering) and the baseline and energy-efficient projections modified accordingly to determine actual savings.

7. **Re-Evaluate at Appropriate Intervals.** Ongoing performance of ECMs or energy-efficient strategies and the associated energy savings must be re-evaluated and verified at intervals and over a time frame appropriate to M&V and related performance contract requirements. This also allows ongoing management and correction of significant deviations from projected performance.

32.3.3 Description of New Construction M&V Options

Method NC-A-01: Stipulated baseline and savings, verified equipment performance

This method is suitable for projects where the potential to perform needs to be verified, but actual savings can be stipulated using estimations of baseline performance and ECM performance based on the verified as-built performance potential. Note that while ECM performance potential must be physically verified (through one-time and/or periodic verification), the savings stipulation is made using assumed typical operating conditions for both the baseline and energy-efficient estimations. Also note that this is a modification of the initial performance estimations that supported the decision to implement the ECM. It is not sufficient to simply use the initial estimates "as-is" without performance potential verification.

Although the most rudimentary of M&V methods, NC-A-01 is adequate for many purposes, including performance contracts. It can be applied to essentially any end-use ECM—motors, lighting ballasts, chillers—and is particularly well suited to constant or predictable loads. The method of verification of performance potential depends on the measure savings uncertainty, the confidence level required, the practicality of physical performance measurement, and M&V costs. The method can range from physical inspection and verification of nameplate data to short-term metering. The following table illustrates the advantages and disadvantages of this method.

Advantages	Disadvantages
• Simplicity • Low cost • Reasonable accuracy with constant or predictable loads	• Diminished accuracy with non-constant or unpredictable loads

Method NC-B-01: Stipulated baseline, savings based on verified equipment performance and estimating tool calibrated with short-or long-term data

This method is suitable for projects where end-use ECM potential to perform needs to be verified, and savings need to be estimated to more accurately reflect actual operating conditions. Performance potential is verified in the same manner as NC-A-01; however, the savings estimation is made by using metered data to adjust and calibrate the savings estimating tool. The metering can be short or long term depending on the constancy and/or predictability of the load. The variables metered can be any factor that materially affects the generation of savings, and can include the consumption of the end use itself. Operating hours and power draw over a period are typical examples. Increased metering complexity produces higher verification accuracy at the expense of M&V cost. Using statistical sampling of similar multiple end-use points (such as motors or lamps) instead of extensive metering is an effective cost-mitigation strategy. The following table illustrates the advantages and disadvantages of this method.

Advantages	Disadvantages
• Relatively simple • Flexibility in trading off metering complexity and cost with accuracy • Ability to isolate and prioritize critical variables affecting savings	• Physical metering or monitoring of necessary variables can be problematic • Metering equipment must be calibrated and maintained

Method NC-C-01: Whole-building baseline simulation, savings based on difference with actual billing data, verified ECM performance

This method is directed at whole buildings where numerous ECMs are installed, are highly interactive, and are integrated into the building design. Installation and operation of the building as-designed must still be verified.

During the building design process, a holistic concept of an energy-efficient building is developed. Such a building may utilize architectural elements such as light shelves, skylights, ground coupling and building orientation to take advantage of natural resources at the building site. In addition, the proposed building may also incorporate high-efficiency equipment such as lighting, motors, controls, and chillers. The energy-efficient building is modeled in a computer simulation to determine its energy performance. Because a major portion of the ECMs in the energy efficient building are architecturally integrated, use of the “ECM subtraction technique” of method NC-D-01 is inappropriate to determine project energy savings. In addition, most building computer simulation packages are incapable of modeling such architecturally integrated elements.

In this method, a baseline building is designed and modeled in compliance with the new building energy performance standard as described in ASHRAE 90.1. The architectural shape of the baseline building needs not precisely resemble that of the proposed energy-efficient building; however, it must have the same floor area, similar surface-area-to-volume ratio, support the same occupancy, comfort and building operation schedule requirements, and any other system function required by the federal agency for the new building.

In most cases, the estimating tool will be an hourly computer energy simulation package. The baseline building is stipulated and modeled in the design process. Actual operating conditions of the as-built building that materially impact energy use are monitored and/or metered throughout the M&V term. These conditions include, at a minimum:

- Weather data
- Occupancy - density and schedule
- HVAC run time and set points
- Lighting schedules
- Plug load power density and schedules.

The baseline simulation model is adjusted and re-run under actual operating conditions for a given period. The resulting adjusted baseline performance is compared to the actual utility billing meter data for the same period to generate the savings. Since there is no real data to check the baseline building model, the baseline model should be reviewed by an independent, qualified third party who is familiar with both ASHRAE standard 90.1 and building simulation modelling. A supplementary quality control reference for the baseline is to compare it with the utility data of similar buildings.

Aside from adjusting simulation models to reflect actual operating conditions, the single greatest factor affecting the accuracy of this method is the quality of computer modeling and simulations. Most hourly simulation programs tend to underestimate actual energy use due to factors such as precise default equipment sizing (i.e., no over-sizing to accommodate equipment increments or safety factors), broad HVAC zoning (due either to zone handling limitations in the software or user lack of attention to detail), and HVAC air volume sizing based solely on thermodynamic requirements. The following table lists the advantages and disadvantages of this method.

Advantages	Disadvantages
• Allows M&V of complex ECMs and holistic buildings • Does not require extensive end-use metering • Encourages integrated building design since M&V considerations do not limit ECMs to end use or discrete systems	• Can be costly due to high level of professional labor • Requires high level of building design and simulation expertise to achieve acceptable accuracy • Monitoring of actual operational conditions can be problematic • Simulation complexity and quality control concerns can be a basis for contention; this is not an analytically "transparent" process

Method NC-C-02: Stipulated baseline, savings based on comparison with similar buildings with and without ECMs

This method is suitable for projects that do not require a high level of savings accuracy and where there is a statistically significant population of existing buildings that are physically and operationally similar to the stipulated baseline building. M&V consists of comparing the actual utility data of the energy-efficient building with data from the existing baseline building(s) for the same period. Some engineering analysis may be necessary to adjust for variations in building configuration or operating conditions. The following table lists the advantages and disadvantages of this method.

Advantages	Disadvantages
• Relatively simple and low cost • Limits technical contentiousness (if method is mutually agreeable in concept)	• May be difficult to find reliable and statistically meaningful baseline comparison buildings • Securing the cooperation of baseline building owners/managers can be problematic • Variability in operation, maintenance, etc., between baseline and energy-efficient building(s) limits accuracy of the method • Accuracy issues limit the method to energy-efficient buildings with ECMs or performance strategies that are expected to generate significant savings; the anticipated savings must substantially exceed the accuracy tolerances of the comparisons

Method NC-D-01: Calibrated whole-building simulation of as-built building, baseline performance defined by "ECM Subtraction Technique," verified ECM performance

This method is directed at buildings where numerous, highly interactive ECMs will be installed, rendering savings estimations of individual ECMs impractical or inappropriate. ECM installation and operation must still be verified. This method is not appropriate for buildings which derive energy efficiency from integrated, holistic building designs. The appropriate method for holistic building designs is method NC-C-01.

During the building design process, the baseline building and energy-efficient building are defined. Energy-efficient lighting, motors, controls, chillers, boilers, and so on that would not be included in the baseline building may be included as part of the proposed energy-efficient building; however, the baseline building must perform to current federal building energy performance standards, which is ASHRAE 90.1.

The energy performance of the baseline building and the energy-efficient building is determined by estimation through computer simulation. In most cases, the estimating tool will be a quality hourly computer simulation program. First year energy and cost savings are estimated during the design process. Verification of the ECMs is achieved through commissioning. Variables that impact the as-built building's energy consumption are monitored beginning in the first year.

After the first year, the simulation model of the as-built building is calibrated against measured building performance data and utility bill data. Whole building computer simulation calibration is described in Section VI. Building energy savings are determined by the "ECM subtraction method" in which ECM performance data are replaced by performance data of the baseline building equipment. The simulation is repeated and annual savings are determined by subtraction of the energy efficient building's annual energy consumption from the baseline building's annual energy consumption, as determined from the modified simulation.

The results of the savings determined from the ECM subtraction method are used to "true-up" the first year savings estimate. Monitoring is continued through the second year and the calibration process repeated. Second year savings are determined by the ECM subtraction method. This process is repeated for the duration of the contract. To reduce M&V expense, monitoring of some building operation variables may be halted if it can be shown that the absence of the data do not impact the simulation calibrations. The following table lists the advantages and disadvantages of this method.

Advantages	Disadvantages
• Obtains most accurate estimation of savings for project	• True-up of savings estimation after first year may be large
• Produces useful calibrated simulation model	• Must wait one year to get accurate results

32.4 Overview Of New Construction M&V Issues

32.4.1 Commissioning

Commissioning of mechanical systems in new buildings is becoming standard practice. Systems commissioning is the process of ensuring that as-built installed systems in new buildings are functioning according to their design intent. For complex ECMs such as HVAC and central plant systems, commissioning is the preferred method of performance verification. Commissioning plans should be developed during the design phase after the ECMs and building systems are identified.

If buildings are to realize the full potential of proposed ECMs, adequate resources must be allocated to the commissioning process. This means that time scheduled for commissioning cannot be arbitrarily reduced, and an independent commissioning authority should be appointed. This person or agency should review the design documents to confirm that there is sufficient information to allow the systems to be correctly commissioned. They should then oversee the complete commissioning process as described in ASHRAE Guideline 1.

Some ECMs, such as natural ventilation, daylighting, nighttime flushing, and use of building thermal mass, result in a building that behaves differently than does a conventional building. It is important that the commissioning contractor, the building maintenance staff, and the occupants understand how the building works.

In addition to performing building commissioning, the design intent and correct operation of ECMs should be documented for the building maintenance staff. The ESCO may even consider conducting training sessions for the staff to further ensure that the ECMs will be properly maintained and operated.

Standards

The suggested minimum standards to be used are as follows:

- NEBB Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems, Vienna, VA: National Environmental Balancing Bureau, 1983.
- AABC National Standards 1982, Washington, DC: Associated Air Balance Council, 1982.
- ASHRAE G-1 Guideline for Commissioning of HVAC Systems, Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1989.
- ANSI/ASHRAE 111, Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigerating Systems, Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1988.
- In addition to recommendations in the above Standards, the Commissioning Authority as defined in ASHRAE G-1 must be independent of the installing contractor.

DDC Commissioning

Nearly all buildings today (aside from very small ones) have some form of direct digital controls (DDC). While procedures for checking valve stroke and operation, location, and calibration of sensors are well documented, there is less clarity on commissioning and verification of the software functions and sequence of operations. It is not the intention of the guidelines to define a commissioning procedure for DDC systems. It is vitally important that the system is correctly commissioned especially if the system is to be used for verifying energy performance. True system verification requires each point and sequence of operation to be checked. For a large and complex building, this may involve two controls engineers for approximately four weeks.

Documenting the Process

Documentation of the commissioning process becomes critical for performance contracting. Clear documentation of all setpoints and air and water quantities as well as any deviations from the design documents will form an essential part of the post-installation verification process. Both the commissioning agent and the performance verification agent need to review the proposed documentation before commissioning starts. This should ensure that the level of information presented in completed documents is adequate for the performance verification method selected.

32.4.2 Using Actual Versus Typical Operating Conditions

Whenever a new building's energy performance is to be compared with an estimate of performance calculated during design, real building performance or input to the calculation has to be modified so that the two can be compared. Even if the new building is being compared to other typical buildings, local climate, occupancy, internal load, etc. must be noted. Some major parameters affecting energy use in real buildings are discussed below.

Weather

Most computer simulations used for estimating energy use typical annual weather data for input. If relevant data are recorded at the building, then the computed energy can be modified to account for actual annual weather conditions. It is important that the actual data recorded matches the input requirements of the computer analysis. For instance, if the program uses hourly weather data, hourly data should be recorded. And if the program uses solar insulation data, this information needs to be measured (a solar pyranometer would not normally be specified for a building control system).

Lighting

Actual lighting load may vary significantly from the lighting-use profile assumed in the computer analysis. Metering the overall power load will not give a true indication of lighting use profiles. If lighting circuits are metered, a better indication can be obtained. For buildings that feature extensive daylighting schemes, the metering of lighting circuits needs to be broken down to fairly small zones so that predicted reductions in lighting energy can be checked against actual use. Monitoring a large number of lighting circuits can be expensive. Alternate methods are to monitor typical circuits on each facade of the building and some interior zones.

Small Power

The issues for small power measurement are similar to those for lighting. Ideally each panel board should be monitored; however, monitoring a representative sample may be sufficient. The practice of estimating cooling loads based on the nameplate rating of computing equipment has led to over-designed systems. Real measurements of power consumption of office equipment over time would be a valuable resource for HVAC system designers. If monitoring of actual power consumption is not available, an actual count of in-use equipment can be made. A few spot measurements of power draw can then be used to estimate the diversity factor to be applied to the equipment ratings.

Occupancy

Occupancy loads are the most difficult building loads to compare. Most computer analysis programs assume a uniform distribution of people throughout the building. In actual buildings, however, neither the total number nor the location of people remain static. The computer analysis assumes an occupancy profile for the building, but in the case of a multi-tenant building, real occupancy profiles may vary significantly from floor to floor. A practical solution to estimating real occupancy profiles is to observe actual occupancy on a few representative days each year, and use these data to extrapolate annual occupancy patterns.

Internal Temperatures

Internal temperature set points are often varied by facility staff in response to occupant complaints. Actual set points must be recorded so that meaningful comparisons can be made with predictions. This information should be available from the energy management system.

User-Controlled Buildings

Naturally ventilated buildings and mixed-mode buildings (combination of natural ventilation and air-conditioning) pose a difficult problem for comparing predicted versus actual operating conditions. These buildings often have high occupant satisfaction due to the fact that occupants have some control over their environment. Tracking these effects is difficult, and is most accurately achieved through EMS or other system sensors.

32.4.3 Computer Simulation Model Issues

All methods (with the exception of NC-C-02) rely on "estimating tools" to generate the necessary baseline and energy efficient performance projections. These tools are presumed to be computer-based and can range in sophistication from spreadsheets programmed using engineering calculation methodologies to hourly whole-building simulations. The level of sophistication should be appropriate for the complexity of the ECMs, the M&V method used, and the necessary degree of accuracy or confidence. Tools used in a performance contract context should not only be mutually agreeable to the parties, but should also be technically comprehensible to all concerned. In this regard, more demanding analyses (such as hourly simulations) should be conducted using one of the more widely recognized and validated packages.

Computer Simulation

The accuracy of computer simulations is an issue that has been the subject of considerable debate in all building engineering sectors. The reality is that most mainstream hourly computer simulation programs tend to underestimate actual energy usage, particularly when applied by less experienced users. Some of the main reasons are:

- Default or automatic HVAC plant and large secondary equipment sizing is usually "right on" the load, with perhaps some provision for a user-specified safety factor. In reality, available equipment capacity increments, load pickup considerations, and redundancy/backup considerations result in considerably larger as-built systems and equipment than the software defaults for auto-sizing.
- HVAC air supply volumes are usually defaulted or auto-sized based only on thermodynamic load. In real practice, air volume required to meet the pure heating or cooling load is usually a fraction of what is normally considered necessary for adequate air circulation in the space. Consequently, default or auto-sizing of air supply volumes inevitably results in a considerably undersized air system in the simulation. This can result in catastrophic underestimation of energy use if a constant volume (CV) reheat-based system is being evaluated.
- The default HVAC configurations and control sequences for ventilation in many programs simply presume an exact specified ventilation rate to the space. This

approach may not consider the practicalities of central air-handling design that drive up the overall building ventilation rate. The result, again, is significant underestimation of energy use in CV reheat-based systems.

- Broad-block HVAC zoning in all simulations results in the mixing and canceling of local heating and cooling loads, which are normally met individually in a properly zoned real-world HVAC system. The result is an energy use underestimation. In this regard, it is a general axiom that the more tightly and accurately the HVAC zoning is modeled, the more accurate the simulation results.
- A related HVAC zoning issue is the “corner office effect.” This occurs when a real-world chronic problem zone (such as a corner office or boardroom) is consolidated into a larger simulation zone. The high chronic load is “diluted,” and sometimes effectively neutralized. This is a serious problem in the simulation of supply air reset strategies. Since the simulation does not “see” a chronic high load area, the supply air reset modulates through a much wider range than would be the real-world case. This results in underestimation of design flow rates, system reheat, and plant energy demand.

The knowledge and experience of the simulation engineer and the rigor of the simulation model are paramount to result accuracy. All of the issues listed above can be avoided, but a thorough understanding of building design principles, with particular emphasis on HVAC design and operation is required. Simulation “shortcuts” and program defaults should only be used if there is a clear understanding of their implications.

In many cases, it is impossible to model all ECMs with a single estimating tool. In these instances it is acceptable to use a number of estimating approaches and consolidate the results in a single final result. Many simulation programs have provisions for manual input to override certain operational variables or factors. Many stock system models or components can be programmed to mimic a non-stock configuration or operational sequence. The latter should only be attempted by the most experienced users.

32.4.4 Use of Energy Management Systems or Data Loggers for Data Collection and Analysis

The building EMS can provide much of the monitoring necessary for the verification process; however, the system and software requirements need to be specified so that the EMS can be a useful tool for verification as well as its primary function of controlling building systems.

There may be parameters that need monitoring for verification, but are not required for control. These points must be specified in the design documents. Electric power metering is an example. Trending of small power, lighting and main feed power consumption may be very useful for high quality verification.

Other functions that can easily be incorporated into the software are automatic recording of changes in set-points. The evaluation team can have a direct read-only connection into the EMS via a modem link. This allows all the trending data to be analyzed and collated by the evaluation team in their office. It is not unusual for many of the trending capabilities required for verification to be incorporated in an EMS. All too often, however, the building facility staff is not properly trained in the use of the system and is unaware of the many additional monitoring and diagnostic capabilities of the system.

32.4.5 Changes in Building Operation and ECMs During Term of Performance Contract

Under a performance contract, all changes in operation, from system on-times to control set-points, must be recorded. Methods for estimating what effect these changes have must be agreed upon, preferably at the start of the contract. Changes in the system due to ECMs can be addressed using the methods already developed for existing buildings. In addition, there may also be changes in set-points during the first year to optimize the performance of the systems. These changes are part of the commissioning process of the original ECMs and so do not require a separate analysis.

Buildings with high turnover rates and changes of occupancy present a significant workload in recording and re-evaluation of energy performance. In many cases these changes may have a significant effect on the building energy consumption; therefore, the method for recording and incorporating them into the verification method must be defined.

32.5 Site-Specific M&V Plans

Issues that need to be addressed in the project-specific M&V plan and that are related to new construction projects include:

- Which analytical tool will be used to calculate savings from ECMs. If the tool is an hourly building simulation package, it should be one of the generally accepted hourly simulation packages, such as DOE2 or BLAST. Also provide the version number, the supplier of the program, and what, if any, pre- and post-processors will be used
- A thorough baseline description must be provided. The scale of this description should be on the order of the scale of the project. Additionally, documentation of how the baseline building meets ASHRAE standard 90.1 must be provided. It should be clear how the energy performance of the baseline building will be obtained.
- Description of post-retrofit building which includes identification of the ECMs to be installed, and how the energy performance of the ECMs will be obtained.
- Description of any building operation conditions (i.e., set-points, schedules) that will be used to predict the baseline and energy-efficient building energy performance.

- Documentation of the ECM or building modeling strategy and project procedure, including how the building models will be calibrated or adjusted with actual measurements or utility bill data.
- Identification of spot and short-term measurements to be made
- Description of commissioning procedures for complex ECMs and related operations manuals to be developed, as necessary.
- For calibrated computer simulation of the new building, documentation of the calibration procedure as specified in Section VI.

33

Operations and Maintenance Measures

This chapter is a "place-holder" for discussing some of the issues associated with M&V of O&M measures. Future efforts by FEMP to develop M&V methods and test them on a range of projects will result in M&V methods for O&M projects being defined in future editions of this document. In the meantime, it is hoped that material in this chapter will help federal agency project managers and procurement officers develop O&M projects and understand the M&V issues that need to be addressed.

33.1 Project Definition

Federal agencies are allowed to use ESPC for installation of O&M measures that can demonstrably reduce facility energy costs and related O&M expenses. Specifically Regulation Section § 8287c. defines the term "energy savings" as a reduction in the cost of energy, from a base cost established through a methodology set forth in the contract, utilized in an existing federally owned building or buildings or other federally owned facilities as a result of:

1. The lease or purchase of operating equipment, improvements, altered operation and maintenance (O&M), or technical services; or
2. The increased efficient use of existing energy sources by cogeneration or heat recovery, excluding any cogeneration process for other than a federally owned building or buildings or other federally owned facilities.

O&M measures do not necessarily involve the installation of new equipment.They can include repairs of defective equipment or equipment that is not operating as efficiently as possible (e.g., broken HVAC economizer systems), commissioning, improved maintenance procedures (including computerized tracking systems), training, or the installation of computerized systems that monitor system performance and report warnings when systems are not operating properly. In some cases O&M measures can include the out-sourcing of facility O&M staffing.

Methods for measuring and verifying O&M project savings are not nearly as developed or tested as methods for the M&V of energy or water projects. As discussed below, there are several issues associated with the M&V of O&M projects that make quantifying baseline conditions, post-installation conditions, and savings very difficult.

Table 33.1 provides an overview of typical O&M measures and associated categories of related savings.

Table 33.1 List of Common O&M Measures and Cost Savings

Measure	Capital Cost Savings	Operating Costs, Energy	Operating Costs, Labor	Operating Costs, Other	Mainte-nance Costs	Conse-quential Costs
Commissioning and "continuous commissioning"	X	X		X	X	X
Improved process and scheduling		X		X	X	
Improved control setpoints		X		X	X	
Improved maintenance, general	X	X		X	X	X
Preventative maintenance programs	X	X			X	X
Predictive maintenance	X	X	X	X	X	X
Proactive maintenance	X	X	X	X	X	X
Monitoring and data logging		X		X	X	X
Training	X	X	X	X	X	X
Outsourcing O&M			X			

Monitoring is included in the above table because it can be a mechanism for reducing O&M costs. Performance monitoring provides an O&M management tool, even without an expert diagnostician. Typical system monitoring will record fuel consumption economies, efficiency, and other conventional performance parameters, often using the EMS. Information from those results often serves to identify warning symptoms for other conditions that need attention, especially when operating conditions are found to fall outside the system design parameters. Staying within design conditions is therefore a measure of O&M effectiveness as well as an operating standard.

33.2 Overview of Operations and Maintenance M&V Issues

The energy and non-energy savings from O&M measures are difficult to quantify because:

- O&M measures are usually not limited to new pieces of equipment whose impacts can be isolated and measured.
- Baseline O&M procedures and costs are difficult to quantify, particularly if the current O&M practices are resulting in sub-standard comfort, equipment lives, indoor air quality, etc.
- Valuation of O&M savings may require trade-offs between short-term and long-term benefits and thus may require a long period of evaluation to determine true net benefits.
- Valuation of O&M costs and savings may involve intangibles such as risk and quality of service.

The following is a discussion of some of the issues associated with quantifying the savings from O&M measures.[1] The issues are compiled into the following categories:

- Valuation of savings
- Determining and adjusting baselines
- Persistence of savings and time period for analysis
- O&M Measure's indirect effects
- Can O&M savings justify M&V/metering activities.

33.2.1 Valuation of Non-Energy Savings

Energy Costs

Many energy cost issues for O&M projects are similar to those for energy-efficiency measures, such as calculating energy costs versus kWh, kW or therm savings; however, other issues such as the trade-off between energy and other non-energy benefits (e.g., comfort) can affect the valuation of the overall O&M project.

Labor Costs

When a project involves reductions in facility staffing as a means of reducing costs, there are several M&V issues (beyond labor relations and equity issues). These M&V issues include defining the baseline cost, tasks and performance of the existing labor force, defining how labor costs will be reduced by the project (and not just transferred to another "accounting category"), and providing sufficient oversight to ensure that the tasks and performance of the labor force's replacement are equal to

1. This discussion is from "Measuring and Verifying Savings from Improvements in Operation and Maintenance of Energy-Consuming Systems in Commercial and Institutional Buildings," Steven R. Schiller and Gale Corsen, Schiller Associates, prepared for Lawrence Berkeley National Laboratory and U.S. Department of Energy's Rebuild America Program, April, 1998.

or above the specified requirements.

Operating Versus Capital Costs Savings
O&M measures can affect both labor cost and capital cost accounting categories, sometimes in opposite directions. Therefore, the M&V process must consider all cost accounting categories that are affected by the O&M measures to ensure that all debits and credits are properly accounted for and used in the calculation of performance.

Another related issue is calculating a potential difference in residual value at the end of the performance period—a concept related to salvage value. For example, an agency would probably rather have performing systems at the end of the contract period instead of systems that are at the end of their useful life.

33.2.2 Determining and Adjusting Baselines

Setting Baseline M&V Procedures
Determining the baseline from which savings are calculated for O&M measures often requires evaluating what the existing standards of performance are for O&M activities. These existing standards are often not well documented and the baseline definition can thus involve identifying the incremental value of "more robust" O&M measures versus "well done, conventional" measures—both of which need to be defined for the calculation of savings. In addition, while the standard for acceptable practice may be defined for the facility, actual practice may be sub-standard. Thus, should the savings be based on the O&M standard or the actual O&M practices?

Adjusting Baselines
Baseline adjustments are one of the more difficult aspects of energy project M&V. Issues associated with energy project baseline adjustments, as discussed in Section I, should be reviewed. Some of the unique issues associated with O&M measures are:

- Adjusting labor costs, equipment repair costs, and equipment replacement schedules based on changes in the facility's operation (e.g., changes to longer life lamps paid for by the facility).
- Period of time for assuming existing baseline conditions (e.g., how long should the current, perhaps poor, maintenance procedures be assumed to have been continued in the absence of the O&M measure).

33.2.3 Persistence of Savings and Time Period for Analysis

A simple O&M measure such as cleaning filters may achieve substantial energy savings, but only so long as people continue the practice. Concerns about persistence apply to a wide variety of maintenance and operational items. Experience tells us that, after certain procedural improvements are made, a tendency to slip back into earlier practices can occur in which clogged filters are continued in use, controls are no longer optimized, drive belts are slipping, and repairs are not made. It is easy to conclude that many O&M measures have short lives.

Another important characteristic of O&M measures is the inherent coupling of short-term and long-term effects. O&M budget cuts "today" do not result in long term savings if they lead to still higher O&M costs "tomorrow."

Long-Term Versus Short-Term Savings

Reducing O&M costs in the short term is relatively easy. It is reducing O&M costs, and related equipment costs, over the long term while maintaining necessary performance levels (e.g., comfort and safety) that is difficult. Thus, M&V of O&M measures will tend to be a lengthy process to ensure that long-term savings are not sacrificed to achieve short-term benefits. This involves evaluating the persistence of savings and life-cycle savings.

Time Period for Analysis of Performance

Several issues arise out of the time period for analysis. A standard response would be that savings should be determined for the full term of the performance contract. If the contract term is relatively short, however, then certain O&M measure impacts might not be considered, whether these are beneficial (e.g., extended equipment life) or not (e.g., shortened equipment life). For longer term contracts, a related question is how long is it "fair" to attribute savings to a measure? For example, some measures might correct deficiencies, such as broken economizer systems, that would have been repaired at some point regardless of a performance-based contract.

33.2.4 O&M Measure's Indirect Effects

Performance Standards

As part of an O&M project, it is important to set facility standards for short-term and long-term satisfactory operations (e.g., comfort, lighting levels, temperature ranges, and air quality.) For the M&V of an O&M measure, it is important to:

1. Define criteria, methods and matrix for evaluating if the facility's performance standards have been met.
2. Define how adjustments will be made if operating standards are currently below standard and will be brought up to standard by the implementation of the O&M measures—e.g., outside air levels are brought up from below standard to levels required by standards. Note that, in some cases, the existing performance will be above standard, such as 100% outside air when it is not required, and the O&M measures may reduce the performance, but not below the set standard.

Valuation of Indirect Benefits

Operating and maintenance practices can have an important bearing on an organization's less tangible costs, such as work stoppages, occupant satisfaction, consequential liability and insurance costs, and other risk factors. Measures for O&M savings have the same potential. These costs are often difficult to identify and even more difficult to value, requiring probability estimates for unlikely but critical events. For example, what if an O&M measure simultaneously changes several factors such as energy, indoor air quality, and comfort; how are these effects accounted for, verified, and measured? What if multiple changes result in degradation of some factor as well as improvements in others—how is this accounted for?

33.2.5 Calculation of Savings and O&M M&V Options

Before defining a framework for calculating O&M savings, the following general points need to be made:

- Savings from O&M measures will typically fall into one or more of the following three categories: energy, labor, and equipment. A possible fourth category is indirects, which (almost by definition) are difficult to measure.
- The baseline costs and performance period costs should be tracked with standard accounting practices. A key is to make sure that all costs are accounted for, including all those which rise or fall, due to the O&M measures.

In general, the baseline labor and equipment costs can be determined by either:

- Use of a "control group" set of facilities, which are similar to the one(s) with the O&M measures, to determine what the O&M costs would have been in the absence of the measures; or
- Use of historical cost data, adjusted as needed to changing needs and uses of the facility (e.g., more operating hours or higher occupancy loads effect on HVAC system operating costs).

There may be a practical minimum threshold, or level of effort, that must be conducted for measuring and verifying the savings from any O&M project; however, this issue is the same as for energy efficiency projects. The level of M&V rigor is going to vary according to (a) the value of the project and its expected benefits and (b) the acceptable level of risk in achieving the benefits.

The following is a discussion of measurement and verification options for O&M measures. They are described per the framework of Option A, B, C, and D (see Section I of this document).

33.2.6 Option A for O&M Measures

Option A is for projects in which confirming the potential to generate savings is the primary objective of the M&V activities—versus the other options, where actual savings are estimated based on actual operating conditions. Therefore, Option A involves determining savings by validating certain key performance criteria (such as the operation of a new O&M software program or repairs to outside air dampers) and stipulating other parameters (such as assumed reductions in labor hours). Payments could be subject to change based on periodic assessments of O&M activities.

Stipulation is the easiest and least expensive method of determining savings. It can also be the least accurate (compared to using long-term measured data) and is typically the method with the greatest uncertainty of determining actual savings. Option A includes procedures for verifying that baseline conditions have been properly defined and the O&M measures, procedures, and/or systems:

- that were to be initiated have been initiated

- meet contract specifications in terms of factors such as quality of service
- are operating and performing in accordance with contract specifications and are meeting all functional tests
- during the term of the contract, continue to meet contract specifications in terms of factors such as quality, operation, and functional performance.

An example of Option A would be for an economizer repair program. The M&V activities would consist of checking the existing condition of the economizers and verifying their repair. A systems model may be used to predict energy use with the economizers in their existing (broken) condition (the baseline) and with properly operating economizers (post-installation energy use). Then savings would be stipulated as the difference between the baseline and post-installation predictions. Then each year of the performance contract the economizers' proper operation would be checked and the savings (payments) would not be re-calculated unless the economizer is not working to specification. The estimated savings would not be adjusted with changes in the weather or operation of the building as a whole.

33.2.7 Option B

Option B is for projects where long-term measurement of performance is desired. Under Option B, individual O&M measures or systems are continuously monitored to determine performance, and this measured performance is compared with baseline values to determine savings. Option B methods provide long-term operating (persistence) data on the O&M measures, procedures, and/or systems. In some cases, these data can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the retrofit. Option B also relies on the direct measurement of affected end uses.

Option B methods involve the use of post-installation measurement of one or more variables. The use of periodic or long-term measurement accounts for operating variations and will more closely approximate actual energy savings than the use of stipulations as defined for Option A. For example, energy use, labor costs, and equipment costs might be tracked after measure implementation for actual comparison with baseline values.

An example of Option B would be for an economizer repair program. The M&V activities would consist of checking the existing condition of the economizers and verifying their repair. Chiller, and related auxiliary energy consumption, would be metered before and after repair of the economizers. The pre-existing energy data and independent variable data would be used to establish a baseline model. Savings would be calculated each year as the difference between the baseline energy model and measured, post-implementation data. The savings would thus be adjusted with changes in the weather or operation of the building as a whole.

An issue with Option B (and C) is that there may be changes that affect post-installation energy, labor, or equipment costs that are not associated with the O&M measures and are beyond the contractor's control. For example, there may be an increase in square footage of conditioned space or an increase in facility operating hours. Therefore, and this can be very complex, data would need to be collected in order to derive correlations between each of the cost categories and key factors such as occupancy, hours of operation, weather, industrial production rates, etc. The baseline would be adjusted to account for these changes depending on which party assumes the risk for changes to each variable.

33.2.8 Option C

Option C involves determining savings by comparing total facility energy and/or O&M costs before and after implementation of the measures. This is a “bottom-line” approach where documented costs (e.g. from utility bills or a company's accounting/ tracking system) are used to identify savings. Option C methods are useful when measuring interactions between systems is desired, when determining the impact of projects that cannot be measured directly, and when a direct connection between the M&V effort and “bottom-line” is desired.

An Option C example would be similar to the one for Option B; however, with Option C, the total costs before and after the out-sourcing would be compared in total versus the comparison of each individual cost category.

33.3 Site-Specific Measurement and Verification Plan

At this time, measurement and verification plans for O&M measures will need to be custom developed by the ESCO and the federal agency since there are no guideline M&V methods (as there are for water and energy measures). It is highly recommended that not only the definition of the measures and their projected savings be established early in the planning process, but also the M&V approach. This is because for all ESPC agreements, the savings must be determined on an annual basis and thus, O&M measures must be defined in a way that their benefits can be quantified. If the O&M measures do not lend themselves to straightforward quantification of savings, the contract negotiations can be held up or there will be significant disputes during the term of the agreement.

The site-specific measurement and verification approach may be pre-specified in the ESPC contract between the federal agency and ESCO and/or agreed to after the award of the project. In either case, prior to the federal agency's approval of project construction, the ESCO will need to submit a final M&V plan that addresses the following elements:

- Describe the facility and the project; include information on how the project saves energy and/or provides non-energy benefits and what key variables effect the realization of savings. An accounting type spreadsheet should be prepared which shows estimated baseline costs and projected performance period costs for categories such as: labor, materials, equipment replacement, energy, and demand. Each of these values will need to be verified (baseline) or determined during the pre- and post-installation M&V processes.

- Indicate how the federal agency's budget will directly be reduced by the implementation of the measure(s). All payments to ESCOs must come from demonstrable savings to the agency's budget.
- Define the baseline O&M performance standard. If this standard is better and more expensive than the existing standard, then document how the baseline O&M budget will be established and calculated.
- Define the minimum performance standards (indoor air, temperature ranges, lighting levels, safety requirements, etc.) that are currently in place and those required once the measure is in place. Determine how benefits (or losses) associated with improvements (or reductions) in performance standards will be allocated between parties. Indicate how compliance with performance standards will be verified during the term of the agreement and what will happen if they are not met.
- Indicate who will conduct the M&V activities and prepare the M&V analyses and documentation.
- Define the details of how calculations will be made and the assumptions that will be made about significant variables or unknowns. For instance, labor cost inflation rates, labor hours per specific task, and equipment life times with and without the new O&M measure. Describe any stipulations that will be made and the source of data for the stipulations. Describe any maintenance/management software that may be used. Show how calculations of O&M savings will be used to determine payments to the ESCO.
- Specify what metering and data logging equipment will be used, who will provide the equipment, its accuracy and calibration procedures, and how data from the metering will be validated and reported, including formats. Electronic formatted data directly from a meter or data logger are usually required for any short- or long-term metering.
- Specify what additional management oversight logs will be maintained, the nature and frequency of entries, and interpretation that is to be assigned to the results. Examples include logging of equipment failures and frequencies, equipment down time, and complaints.
- Describe any sampling that will be used, why it is required, sample sizes, documentation on how sample sizes were selected, and information on how random sample points will be selected.
- Define the level of accuracy which should be achieved for at least the key components if not for the entire analysis.
- Indicate how quality assurance will be maintained and repeatability confirmed. For instance, "The data being collected will be checked every month and provided to the federal agency."
- Indicate which reports will be prepared, what they will contain, and when they will be provided.

34

Cogeneration Projects

This chapter introduces methods for determining savings from cogeneration projects and discusses some associated issues. As the number of cogeneration projects implemented through federal ESPCs increases, FEMP may develop more detailed M&V methods for inclusion in future editions of this document. In the meantime, it is hoped that material in this chapter will help federal agency project managers develop cogeneration projects and understand the M&V issues that need to be addressed.

34.1 Measure Definition

Federal agencies are allowed to use ESPCs for installation of cogeneration projects that can demonstrably reduce facility energy costs and related O&M expenses. Specifically, Regulation Section § 8287c. defines the term "energy savings" as a reduction in the cost of energy, from a base cost established through a methodology set forth in the contract, utilized in an existing federally owned building or buildings or other federally owned facilities as a result of:

1. The lease or purchase of operating equipment, improvements, altered operation and maintenance, or technical services; or
2. The increased efficient use of existing energy sources by cogeneration or heat recovery, excluding any cogeneration process for other than a federally owned building or buildings or other federally owned facilities.

Cogeneration is the simultaneous generation of both electricity and thermal energy. Typical systems include packaged, gas turbines, and reciprocating engines with heat-recovery systems that can provide steam, hot water, or even chilled water through the use of thermal input chillers.

Depending on the performance contract arrangement the ESCO may either (a) simply provide the agency with thermal and electrical energy, at a discount to the baseline costs, or (b) share the net benefits of the entire cogeneration system—i.e., a shared savings contract. Net benefits would be equal electrical and thermal output value and lower capital costs, fuel costs, and incremental O&M costs.

34.2 Overview of M&V Methods For Cogeneration Projects

Determining the electrical and thermal output of cogeneration systems is relatively straightforward because fuel input and electrical output can be measured simply with many commercially available meters. Measuring thermal output (steam, hot water, or chilled water) of cogeneration systems is also straightforward, although not necessarily inexpensive, using commercial steam meters, water flow meters, and temperature transducers.

Determining the full impact of changes in utility and O&M costs can be more complex because the analysis should include allowances for interconnect safety, rate changes, standby charges, air-quality control requirements, and the need to reject excess heat; all of which the agency will need to account for if the ESCO does not have full operating responsibility under the performance contract.

For determining savings, two general approaches may be used:

1. “One-for-one replacement” calculation
2. Net benefits calculation.

34.2.1 One-for-One Replacement

This concept assumes that energy (electrical and thermal) produced by the cogeneration system, and used in the facility, displaces energy that would have been provided by an existing source. Savings calculations depend on the type of financial arrangement—whether the ESCO is selling discounted electrical and thermal energy or whether it is a shared savings arrangement. The most likely application for this one-for-one replacement approach is the discounted energy cost arrangement in which energy savings are equal to the useful production of the cogeneration system. With the one-for-one replacement concept, all one has to do is (1) measure the net amount of energy produced by the cogeneration system and used in the facility, and (2) calculate the net economic value of the energy produced compared to what has been replaced. With some projects the value of reduced O&M costs are included in the calculation of benefits.

34.2.2 Net Energy-Use Analysis

The net energy-use analysis approach is similar to Option B or C for energy-efficiency projects. Energy and operating costs for the facility (e.g., utility-supplied gas and electricity, any energy sales to other sites, labor costs, insurance costs) are compared before and after the cogeneration system is installed to estimate the net benefit provided by the cogeneration system. This approach is most common with the shared savings financial arrangement. This approach is more complicated because (a) baseline fuel and operations costs need to be quantified, and (b) O&M costs need to be quantified and it is often difficult to allocate costs between the base case, the cogeneration system, and the non-cogeneration systems after the cogeneration system is installed.

34.3 Overview of Cogeneration M&V Issues

Several key issues for evaluating cogeneration projects are:

- Benefits to the facility are usually calculated based on the portion of the cogeneration output (thermal and electrical) that is actually used by the facility, versus total production. Net useful energy production may not be as easy to isolate and measure as gross production. Consideration should be given to items such as amount of vented steam versus delivered steam, enthalpy values of the thermal output (e.g. steam) versus enthalpy values of the thermal stream returned to the cogeneration system (e.g. condensate), parasitic power losses, and heat and power sales to other parties (e.g. back to the utility). As a side note, some contracts will have provisions for how much energy the facility has to take, as a minimum, which can affect actual payments to the ESCO.
- Determining the economic value of the energy provided by the cogeneration system requires information on the value of the energy—i.e., what it would cost to purchase the energy from the existing sources, such as the utility or from a boiler plant. On the electrical side of the equation, current rate schedules should be used and the parties should take into account all changes in customer charges, stand-by charges, and rate structures due to the installation of the cogeneration system. For the thermal side the current rate schedules need to be used for the displaced fuel (e.g., natural gas for boilers or electricity for chillers) and the efficiency of the baseline thermal systems needs to be determined (e.g., boiler, hot water generator, or chiller efficiency) in order to calculate the value of the displaced thermal energy (e.g., steam, hot water, or chilled water).
- Correct incremental O&M costs associated with the existing (baseline) systems and the new cogeneration project need to be defined and used in the analyses. This is true for both the net energy benefit analysis approach or the one-for-one replacement approach. For the net benefit approach O&M costs are used to determine net savings. For the one-for-one replacement approach, O&M costs can be used in the thermal energy price calculation (e.g., eliminated labor costs associated with steam production are included in the price per pound of steam). These O&M costs can include hard-to-quantify changes in labor, repairs, insurance, management support, spare part requirements, air emissions monitoring and reporting, and subcontracted services.
- Predicting and verifying electrical demand savings is one of the more difficult aspects of evaluating cogeneration projects. Demand savings are affected by the load profile of the facility and the output profile of the cogeneration system, whether it has a constant electrical output or is load following. Also note that demand-savings calculations need to take into account down times for the cogeneration system, when downtimes occur (with respect to the facility's peak demand), and the servicing utility's rate structure (particularly if demand ratchets are part of the rate structure). Restructuring of the electric industry and the ability of agencies to buy power on the spot market can also complicate calculations of demand savings and energy purchases in general.

34.4 Information on Metering

34.4.1 Electrical Metering

For electrical savings, meter(s) will typically show the project's gross output, in kW and kWh, less station use, less any plant loads and sales to third parties or the local utility, and local transformation and transmission losses. Metering will typically be for output after station power and losses, either as the aggregate of several meters or as a total with sub-metering for third-party sales; the performance contract will dictate the accounting for the third-party sales. The goal is usually to measure net generation delivered to the federal agency's facilities. Metering, interconnection (including safety provisions), reporting, and other related issues are to be in accordance with current electrical standards and the requirements of the servicing electric utility.

Metering requirements will be similar to, if not identical to, the general requirements for metering the supply of electric service by the electric utility. Therefore, a copy of any electric service requirements documents should be obtained from the utility and referred to for general requirements such as access height and enclosure standards.

Electricity measurements associated with generator output, parasitic loads, and power to the facility, as well as to third parties and the utility, may be needed. Note that power may flow into or out of the plant at different times. Deliveries to and from the facility should be separately recorded and treated as separate transactions. For purposes of power delivered to the facility, a single meter that records energy supplied to the facility is preferred. If a calculated transformer loss value is used, it must be based on certified factory test data for that particular transformer supplied by the manufacturer and accepted by the agency and the ESCO.

All electrical meters (and related equipment) are usually provided, installed, owned, and maintained by the ESCO. This should include all mounting structures, conduits, meter sockets, meter socket enclosures, metering transformer cabinets, and switchboard service sections of a size and type approved by the agency and the local utility. The ESCO may also need to install net generator metering for establishing cogeneration qualifying facility status as outlined in the Code of Federal Regulations (18 CFR 292; Public Utility Regulatory Policies Act).

The following are some suggested metering requirements differentiated by electrical output of the cogeneration system. Note that all meters should be equipped with detents that prevent reverse registration.

Projects with capacity rated at 200 kW or less
The following meter requirements apply:

- kWh and demand metering at the Point of Delivery.

Projects with capacity rated at greater than 200 kW
The following meter requirements apply:

- kWh and demand metering at the point of delivery
- kVarh meter
- Time-of-delivery pricing metering
- Conduit to accommodate a telephone line for remote meter reading
- Load profile recording equipment at the point of delivery, with graphic recorder or data logger.

34.4.2 Thermal Metering

Thermal savings meters are required for measuring the net thermal output of the cogeneration system. Depending on the contractual arrangements, the metering can be at (in order of likelihood):

- The heat recovery system of the cogeneration—i.e. measuring net output of the cogeneration system, typically steam or hot water
- The output of a conversion device that uses the thermal output of the heat recovery system, e.g., a steam driven chiller, in which case chilled water might be measured
- The delivery points of the thermal energy—i.e., where hot water enters the building hot HVAC coils.

Note that metering thermal energy requires a "net" measurement of flows and enthalpy to and from a system. Measurements of thermal flows may need to take into account any vented or wasted energy that is produced by the cogeneration system but not used at the facility. Also note that small errors in enthalpy measurements (usually determined by temperature) can introduce large errors in the energy calculations, so meter precision, accuracy, and calibration are especially important.

Finally, a word of caution concerning steam flow measurements. Steam flow and enthalpy measurements are difficult. For good accuracy, very good meters and careful calibration are required. Often existing steam meters, which have been in place for long periods of time, are not accurate and thus provide questionable historical and current steam-flow consumption data.

For any fuel input metering, the general principle is that metering should comply with standard utility operating practices.

34.5 Equations for Calculating Savings

The general format for calculating savings from cogeneration projects is shown below for two M&V approaches.

34.5.1 One-for-One Replacement Calculation

Savings to federal agency equal:

(electrical energy delivered and used at facility) x (electric rate)

+

[(thermal energy delivered and used) x (rates for displaced fuel) / (efficiency of displaced system)].

34.5.2 Net Benefits Calculation

Savings to federal agency equal:

(electrical energy delivered and used at facility) x (electric rate)

+

[(thermal energy delivered and used) x (rates for displaced fuel) / (efficiency of displaced system)]

+

(value of any thermal energy or electricity sold to other sites/utility)

-

(cost of fuel)

-

(cost of incremental operations and maintenance, including any utility and capital costs).

34.6 Site-Specific Measurement and Verification Plan

Measurement and verification plans for cogeneration projects will need to be custom developed by the ESCO and the federal agency since each project is usually unique, and there are no guideline M&V methods (as there are for water and energy measures). The site-specific measurement and verification approach may be pre-specified in the ESPC contract between the federal agency and ESCO and/or agreed to after the award of the project. In either case, prior to the federal agency's approval of project construction, the ESCO will need to submit a final M&V plan that addresses the following elements:

- Describe the facility and the project; include information on how the project saves energy and/or provides non-energy benefits and what key variables effect the realization of savings. An accounting-type spreadsheet should be prepared which shows estimated baseline costs and projected performance period costs for categories such as electricity and fuel purchases (rates, total costs, and consumption), labor, materials, and equipment replacement. Each of these values will need to be verified (baseline) or determined during the pre- and post-installation M&V processes. To determine the savings from cogeneration projects (particularly demand savings), it is usually necessary to prepare time-of-use analyses for typical days or weeks, if not for the whole year.

- Indicate how the federal agency's budget will be directly reduced by the implementation of the project. All payments to ESCOs must come from demonstrable savings to the agency's budget.
- Define the minimum performance standards (e.g., steam quality or voltage over and under frequency standards) that are currently in place and those required once the measure is in place. Determine how benefits (or losses) associated with improvements (or reductions) in performance standards will be allocated between parties. Indicate how compliance with performance standards will be verified during the term of the agreement.
- Indicate who will conduct the M&V activities and prepare analyses and documentation.
- Define the details of how calculations will be made and the assumptions that will be made about significant variables or unknowns. For instance: labor cost inflation rates, labor hours per specific task, and utility rate schedules (including stand-by rates) with and without the new cogeneration measure. Describe any stipulations that will be made and the source of data for the stipulations. Describe any tracking software that may be used. Show how calculations of savings will be used to determine payments to the ESCO.
- Specify what metering and data logging equipment will be used, who will provide the equipment, its accuracy and calibration procedures, and how data from the metering will be validated and reported, including formats. Electronic formatted data directly from a meter or data logger is usually required.
- Specify what additional management oversight logs will be maintained, the nature and frequency of entries, and the interpretation that is to be assigned to the results. Examples include logging of equipment failures, equipment down time, and system outputs.
- Indicate how quality assurance will be maintained and repeatability confirmed. For instance, “The data being collected will be checked every month and provided to the federal agency.”
- Indicate which reports will be prepared, what they will contain, and when they will be provided.

35

Renewable Energy Projects

This chapter introduces methods for determining savings from renewable energy projects and discusses some associated issues. As the number of renewable energy projects implemented through federal energy service performance contracts (ESPCs) increases, FEMP may develop more detailed M&V methods for inclusion in future editions of this document. In the meantime, it is hoped that material in this chapter will help federal agency project managers develop renewable energy projects and understand the M&V issues that need to be addressed.[1]

While renewable energy system technologies are well established, the initial capital costs of these systems tends to discourage their adoption. In addition, they are still considered experimental by many ESCOs, federal agencies, and design professionals. Thus, M&V guidelines are intended for (a) documenting the benefits of federal ESPC projects and serving as the basis for payments in a performance based contract, (b) assisting in the commissioning process and ongoing diagnostics that can help sustain benefits, and (c) allaying the concerns of ESPC participants and to assist them in adopting renewable energy technologies.

35.1 Measure Definition

Federal agencies are allowed to use ESPCs for installing renewable energy projects that can demonstrably reduce facility energy costs and related O&M expenses.

The renewables projects covered by this chapter are the installation of devices and/or systems that generate energy (electricity or heat) or displace energy use thorough the use of renewable energy resources. Examples of technologies include photovoltaics (PV), active or passive solar systems for space conditioning, or the production of domestic hot water, ground-source heat pumps, biomass conversion systems (e.g., landfill gas methane recovery projects), and wind systems. Some of these systems, such as ground source heat pumps and architectural passive solar systems, could most likely use the M&V methods described in other chapters of this document.

1. Portions of this chapter are from the initial draft materials prepared for the 1999 version of the IPMVP, which, when published, may provide additional resources for the measurement and verification of renewable energy projects. See www.ipmvp.org links to renewables M&V or contact Arlene Thompson and Randy Walker of the National Renewable Energy Laboratory.

Depending on the performance contract arrangement, the ESCO may either (a) simply provide the federal agency with thermal and electrical energy at a discount to the baseline costs (i.e., a guaranteed savings contract) or (b) share the net economic benefits of the renewable energy system (i.e., a shared savings contract). Net benefits would equal electrical and/or thermal output value less capital costs, fuel costs, and incremental O&M costs.

35.2 Overview of Methods

Each of the four M&V options, with modification, can be used for renewable energy projects:

- Option A: Measured verification of equipment rating and capacity with performance based on stipulated production and/or consumption values. An example would be verifying solar thermal collector performance values and then using typical year solar insolation values to calculate hot water production.
- Option B: Measured production and consumption at the system level can be used with most renewables projects with mechanical and/or electrical sub-systems. Architectural passive solar systems can usually not take advantage of Option B. An example would be measuring the thermal output of a solar collector system to determine the amount of hot water that is produced and that displaces conventional fuels.
- Option C: Whole facility or sub-meter analysis can be used to compare conventional fuel use before and after the installation of a renewable energy project. An example would be comparing natural gas use in a facility before and after a solar thermal collector system is installed to displace conventional, domestic hot-water production.
- Option D: Calibrated simulation can be used to model the expected performance of a renewable energy system, with calibration of key parameters using short-term metering or performance tests. An example would be using a computer simulation model, calibrated with short-term performance data, to predict long-term savings from the installation of a solar-thermal collector system.

There are two general approaches for calculating energy savings for purposes of determining payments in an ESPC:

1. “One-for-one replacement” calculation
2. Net-benefits calculation.

35.2.1 One-for-One Replacement

This concept assumes that energy (electrical and/or thermal) produced by the renewable system, and used at the project site, displaces energy that would have been provided by an existing source. With one-for-one replacement, all one has to do is measure the net amount of energy produced by the renewable system and used at the project site. This approach is most common with photovoltaic, wind, and biomass energy production projects. This approach would most likely be used with M&V Options A, B, or D.

35.2.2 Net Energy-Use Analysis

With this approach, which can be used with all four M&V options, electrical energy use at the project site is compared before and after the system is installed to estimate the net benefit provided by the renewable energy system. This approach is most common with solar-thermal systems, particularly when dealing with energy storage issues.

35.3 Information on Metering

Determining the electrical output of systems is relatively straightforward. This is because electrical output and parasitic loads can be simply measured with many commercially available meters. Measuring thermal output (e.g., hot water from a domestic hot water solar system displacing an electric water heating system) is also straightforward, although not necessarily inexpensive, using commercial Btu meters, water flow meters, or temperature transducers. All of the thermal and electrical output from a system, however, does not necessarily displace an equivalent amount of load. This is due to storage, differences in time between when useful energy is produced and when it is needed, and system losses.

35.3.1 Electrical Metering

Electricity measurements associated with generator output, parasitic loads, power to the project site as well as power to third parties and the utility may be needed. All electrical meters (and related equipment) are usually provided, installed, owned, and maintained by the ESCO or the servicing utility.

With the one-for-one replacement approach, meter(s) will typically show the measure's gross output (in kW and kWh) less parasitic use (e.g., pump motors) and sales to third parties or the local utility, as well as any local transformation and transmission and battery storage losses. The goal of this method is usually to measure net generation delivered to the project site. Metering, interconnection (including safety provisions), reporting and other related issues are to be in accordance with current electrical standards and the requirements of the servicing electric utility.

With the net energy-use approach, deliveries to and from the facility should be separately recorded and treated as separate transactions. Note that power may flow into or out of the “plant” at different times and thus detents that prevent reverse registration may be required. For purposes of power delivered to the site, a single meter that records energy supplied to the site is preferred. If a calculated transformer loss value is used, it must be based on certified factory test data for that particular transformer supplied by the manufacturer and acceptable to the ESCO and federal agency.

The following are some suggested metering requirements:

- kWh and demand metering at the point of delivery
- Time-of-delivery metering
- Conduit to accommodate a telephone line for remote meter reading
- Load profile recording equipment at the point of delivery, with graphic recorder or data logger.

35.3.2 Thermal Metering

Thermal meters (e.g., Btu meters) are required for measuring the net thermal output of certain renewable energy systems, such as hot water generated by an active solar system. Note that metering of thermal energy requires a "net" measurement of flows and enthalpy to and from a system. Measurements of thermal flows may need to take into account any vented or wasted energy that is produced by the system but not used at the site, as well as distribution and storage losses. Also note that small errors in enthalpy measurements (usually determined by temperature) can introduce large errors in the energy calculations, so meter precision, accuracy, and calibration are especially important.

35.4 Equations for Calculating Savings

The general format for calculating savings from renewable energy projects is shown below for two M&V approaches.

35.4.1 One-for-One Replacement Calculation

Savings to federal agency equal:

(electrical energy delivered and used at facility) x (electric rate)
+
[(thermal energy delivered and used) x (rates for displaced fuel) / (efficiency of displaced system)].

35.4.2 Net Benefits Calculation

Savings to federal agency equal:

(electrical energy delivered and used at facility) x (electric rate)
+
[(thermal energy delivered and used) x (rates for displaced fuel) / (efficiency of displaced system)]
+
(value of any thermal energy or electricity sold to other sites/utility)
-
(cost of any fuel or electricity used for parasitic systems)
-
(cost of incremental operations and maintenance and capital).

35.5 Notes on Renewable Energy Project M&V

35.5.1 Active Solar Thermal Systems

Active solar thermal systems include systems for producing industrial process heat, domestic hot water, and space heating and cooling. Useful monitoring includes (a) site inspections and brief temperature and system monitoring for diagnostics, (b) spot, short-term, or long-term monitoring of system key parameters such as temperatures, energy flows, and control status, and (c) utility billing analyses.

35.5.2 Passive Solar Systems

Passive solar systems usually involve the performance of a whole building with architectural features such as overhang design and use of thermal mass. As such, this technology is different from other renewable energy measures in that mechanical devices with identifiable energy inputs and outputs are not involved. Thus, passive solar M&V typically involves the analysis of a whole building and it is best to use utility billing analyses and calibrated simulation techniques—Options C and D.

35.5.3 Wind, PV, and Other Renewable Generation Projects

With these types of systems the performance characteristics of the components are usually well defined, such as the conversion efficiency of the PV modules or the Btu content of landfill gas. In addition, the electrical or thermal flows can usually be easily measured. The complexity of these projects is in projecting long-term performance due to variation in the resources (e.g., solar insolation, wind resource, or reserve of methane gas in a landfill) and accounting for any variations between when the resource is available and when it is needed—i.e., the interaction of storage systems and their inefficiencies.

35.6 Site-Specific Measurement and Verification Plan

M&V plans for renewable energy projects will need to be custom developed by the ESCO and the federal agency since each project is usually unique, and there are no guideline M&V methods (as there are for water and energy measures). The site-specific measurement and verification approach may be pre-specified in the ESPC contract between the federal agency and ESCO and/or agreed to after the award of the project. In either case, prior to the federal agency's approval of project construction, the ESCO will need to submit a final M&V plan that addresses the following elements:

- Describe the facility and the project; include information on how the project saves energy and/or provides non-energy benefits and what key variables effect the realization of savings. An accounting-type spreadsheet should be prepared which shows estimated baseline costs and projected performance period costs for categories such as: electricity and fuel purchases (rates, total costs, and consumption), labor, materials, and equipment replacement. Each of these values will need to be verified (baseline) or determined during the pre- and post-installation M&V processes. To determine the savings from renewables projects (particularly demand savings), it is usually necessary to prepare time-of-use analyses for typical days or week, if not for the whole year.

- Indicate how the federal agency's budget will be directly reduced by the implementation of the project. All payments to ESCOs must come from demonstrable savings to the agency's budget.
- Define the minimum performance standards (e.g., minimum hot water temperatures or voltage over- and under -frequency standards) that are currently in place and those required once the measure is in place. Determine how benefits (or losses) associated with improvements (or reductions) in performance standards will be allocated between parties. Indicate how compliance with performance standards will be verified during the term of the agreement.
- Indicate who will conduct the M&V activities and prepare analyses and documentation.
- Define the details of how calculations will be made and the assumptions that will be made about significant variables or unknowns. For instance: utility rate schedules (including stand-by rates) with and without the new renewables measures and sources for solar or wind resource data. Describe any stipulations that will be made and the source of data for the stipulations. Describe any tracking software that may be used. Show how calculations of savings will be used to determine payments to the ESCO.
- Specify what metering and data logging equipment will be used, who will provide the equipment, its accuracy and calibration procedures, and how data from the metering will be validated and reported, including formats. Electronic formatted data directly from a meter or data logger is usually required.
- Specify what additional management oversight logs will be maintained, the nature and frequency of entries, and the interpretation that is to be assigned to the results. Examples include logging equipment failures, equipment down time, and system outputs.
- Indicate how quality assurance will be maintained and repeatability confirmed. For instance, "The data being collected will be checked every month and provided to the federal agency."
- Indicate which reports will be prepared, what they will contain, and when they will be provided.